Consumption Management Software for Electric Power Suppliers

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The electricity market is a very complex reality, with numerous participants, rules, factors that influence the evolution of energy production and consumption. This paper presents a software solution that supports electric power suppliers as participants in this complex market. The prototype uses machine learning algorithms to determine consumer clusters and forecast the next day's consumption, the purpose being to obtain the flattening of the consumption curve at the level of the electricity supplier. Based on the initial consumption planning of programmable devices transmitted by consumers, four consumption optimization algorithms are applied in parallel, giving the energy supplier the possibility to decide the optimal plan for the next day.
Keywords: *power sector, software, power suppliers, forecast, optimization.*

1 Introduction

With the liberalization of the electricity market, the market participants faced a diversification of business models and services types and the need to adapt to the new market rules. In the case of electricity suppliers, these challenges were mainly related to establishing optimal tariff schemes, optimizing consumption and forecasting consumption in order to mitigate the costs of imbalances and ensure the economic efficiency and reliability of energy supply.

The software solution presented in the following sections represents a part of a multi-modular information system for the management of the Romanian electricity market, SMARTRADE [1]. The SMARTRADE project aimed to design and develop a prototype information system for forecasting, analysis and decision models for electricity market participants (suppliers / producers) established as Responsible Parties for Balancing (PRE), in order to estimate consumption and production and carry out efficient transactions on the wholesale electricity market. The objectives of the project are correlated with the current needs of integrating a large volume of electricity produced from renewable energy sources (RES) and, at the same time, with the need to implement smart electricity metering systems (smart metering) for consumers by 2020.

The module, called EL- Supplier, aims to provide a solution to respond to consumer's electricity demand, by implementing not only consumers related data management but also some algorithms that will assist the supplier in making decisions: a consumption prediction models, a model for determining consumption profiles and models for consumption optimization. The analysis results are presented in a friendly and intuitive manner.

The paper is structured in four parts, as follows: section 2 - a brief presentation of the Romanian electricity market and the specific elements of electricity suppliers; section 3 - a presentation of the module for data management of electricity consumers; section 4 - a presentation of the module for electricity consumption management; section 5 - conclusions, advantages and future directions.

2 Electric power suppliers

The Wholesale Electricity Market is the organized framework in which electricity is purchased by suppliers from producers or other suppliers, in order to resell it or for their own consumption, as well as by network operators to cover their own technological consumption. The competitive wholesale market (free market) consists of:

(a) contracts for the purchase / sale of electricity, with quantities and prices negotiated between market participants (producers, wholesale suppliers, eligible consumers).

(b) the "a day-ahead" spot market, with marginal price transactions, for the balancing quantities of the forecasted consumption and the quantities of electricity contracted for each hour of the day.

The system of regulated and competitive markets operating in parallel has the advantage of allowing the development of bilateral relations between producers or wholesale suppliers, on the one hand, and eligible consumers, on the other hand, as the market is open to competition [2]. An eligible consumer is a consumer that is free to purchase electricity from any supplier and has access to the transmission and distribution networks [3].

All participants in the electricity market operate on the basis of accreditations granted by the Romanian Energy Regulatory Authority (ANRE) [4], and their activities are interdependent, the energy not being able to reach the final consumer if one of these actors does not work. In Romania, the meeting place between producers, large industries, suppliers or exporters is the Romanian Gas and Electricity Market Operator (OPCOM) [5], which has the role of managing the electricity market. It is an operator licensed by the National Energy Regulatory Authority (ANRE) and manages several markets, such as green certificates or the day-ahead market.

As an actor in the electricity market, the supplier is the one who ensures the connection with the final consumer, either domestic or non-domestic. The list provided by ANRE in October 2019 included 85 energy suppliers, the competition being very high. Electricity suppliers can have a wide portfolio of consumers of different types (industrial, commercial and residential). Customers have the option to choose a regulated electricity offer from a supplier that has been designated by ANRE as a Supplier of Last Instance or to be an eligible customer and benefit from a free market offer, with a price in a competitive regime.

In the case of tenders with regulated energy supply prices, it is the regulatory authority that determines whether an energy supplier can be a supplier of last resort, and the areas on which a supplier operates in this capacity, as well as the prices for active energy, for each area and for each voltage level. In this way, a supplier can operate in both the regulated market and the free market, having the possibility to offer customers all the variants. However, this option will disappear, by the gradual transition to an exclusive competitive market until 2022.

In the case of offers from the competitive market, the selling prices of active energy are established by each company, depending on the strategy it approaches and, of course, taking into account the price at which it purchases energy. The final value that the customer gets to pay on an electricity bill consists of the actual price of energy, expressed in the currency / MWh and the tariffs regulated by ANRE. They include the distribution tariff (different depending on the area where find out the customer), the transport tariff, the network extraction tariff and the system services, as well as excises, green certificates or the contribution for cogeneration. Thus, except for regulated tariffs which are mandatory and applied by each supplier, the difference between the offers on the market is determined only by the price of active energy and possibly by the extra services that a supplier can offer.

Considering the strong competition existing

on the electricity suppliers market, the efficient management of the data of the associated consumers, their analysis and the taking of informed business decisions becomes a particularly important advantage. This is the reason for developing the software prototype presented in this paper.

The module for managing electricity consumption from the perspective of electricity suppliers, called EL-Supplier, is developed in JDeveloper based on test data previously uploaded to the SMARTRADE prototype database. The module is implemented in the Cloud Computing architecture and can be accessed online through web browsers. The database, which runs on an Oracle Database 12c instance, maintains historical values of electricity demand and generation for more than 5 years.

The following sections detail the steps required to access the module and work with the functionalities implemented to profile consumers, forecast consumption and optimize consumption at the supplier level.

3 EL-Supplier: Data management module

It is a module that ensures the easy organization and retrieval of data on suppliers, affiliated consumers - with their places of consumption, meters, meter readings, tariff allocations, appliances and appliance readings, but also information about the locations and tariffs managed by that supplier.

The supplier can complete and update his personal data regarding name, CUI, address, bank account, email, phone and other contact details. It can also complete / update its data regarding its identification and authorization as a participant on the electricity market.

Through the web interfaces that the solution provides, the user can add or edit data on all consumers associated with that supplier, with all the details that they involve. The software application is organized in several important sections, presented below.

3.1. Supplier info

This option allows you to add / edit general consumer data in the system by filling in the information related to its name, type, address and contact details.

3.2. Consumption place

The module allows to add / edit the details of a certain place of consumption of a consumer in order to achieve consumption profiles by filling in the information related to: type of place of consumption, facilities related to gas supply, existence of own generation sources, capacity and type their number of inhabitants and other details on the characteristics of the consumption place.

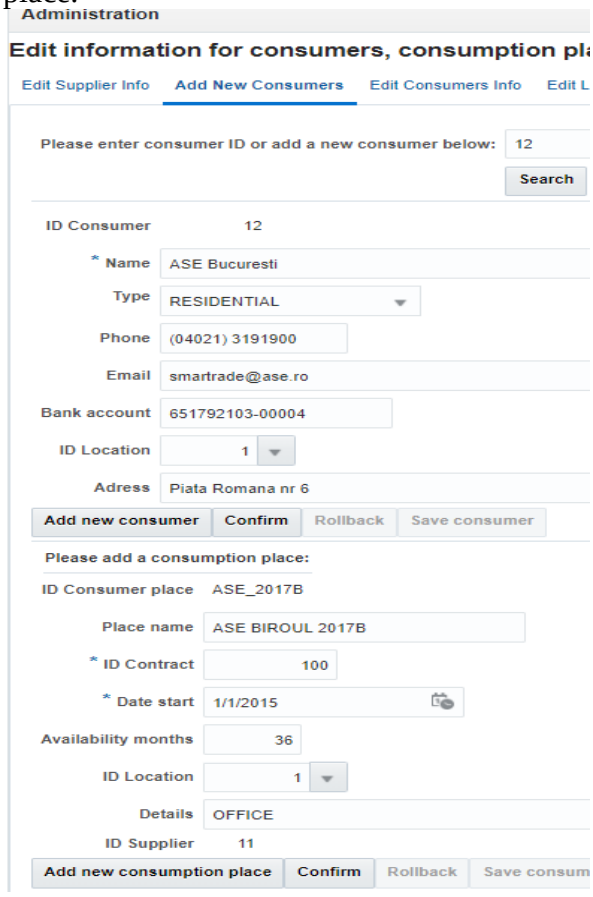

Fig. 1. Details about a consumer and his consumption places

3.3. Meters

For each consumption location, the supplier

configures the operating parameters of the smart meters installed in the respective location: meter identifier, installation date, activation date and meter type. The supplier can later edit and update the meter details. Each smart meter will record the following values: reading date, active, reactive and apparent power consumed, active, reactive and apparent power generated, meter status at the time of reading and recording status (valid or erroneous).

3.4. Meter readings

The data collected by the meters can be viewed in real time or aggregated, subsequently consulted by the supplier and the consumer through the interfaces of the computer system.

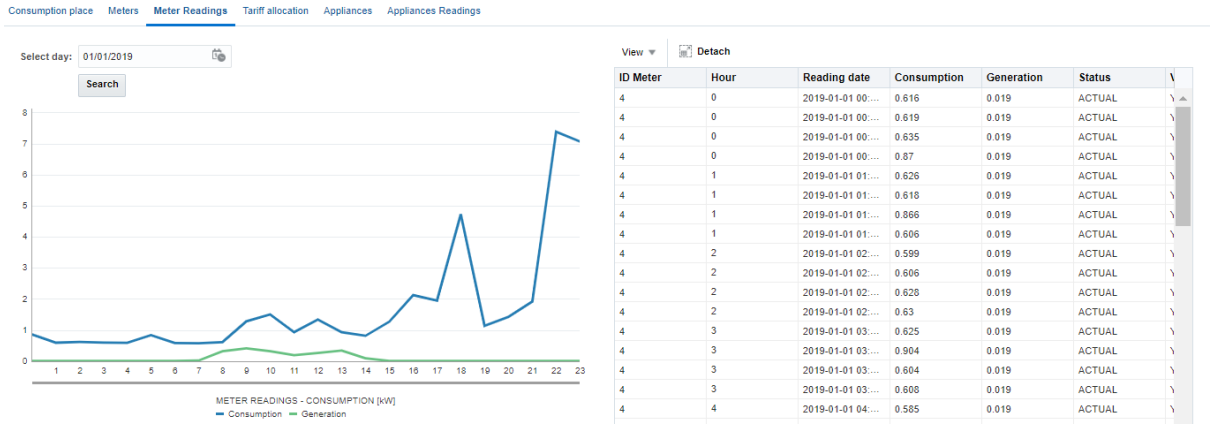

Fig. 2. Hourly consumption recorded by the meter readings for the selected day

3.5. Edit tariffs

Establishing consumer tariff plans is a strategic activity of the supplier and involves modelling consumer behaviour based on consumption profiles, but also considering strategies for participation in the electricity market [7]. The supplier establishes for each consumer's place of consumption a tariff plan according to the consumption profile and the negotiations carried out with him. Thus, following the analysis of the cluster to which the consumer belongs, the supplier proposes a tariff plan for a place of consumption and informs the consumer. He may negotiate the proposed tariff plan and after negotiation the supplier shall associate the tariff plan with him.

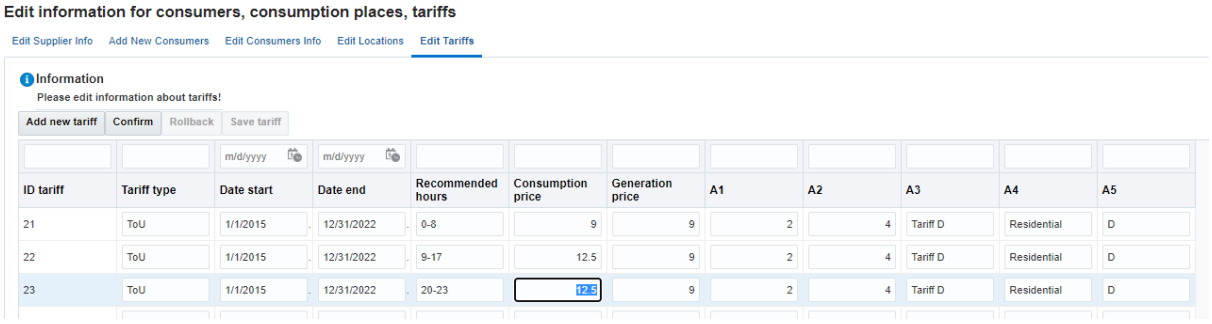

Fig. 3. Edit tariffs

4 EL-Supplier: Consume management module

This module is responsible for viewing consumer's profiles, forecasting and optimizing community consumption. It includes these three functionalities that are going to be presented in detail in the next sub-sections.

4.1. Consumer profiles

In the View profiles tab, a group of

consumers affiliated to the selected supplier will be made according to the number of clusters desired for each quarter. A clustering method using k-means is run to group the electricity consumers into consumption groups with similar behaviour.

For example, select the number of profiles (or clusters) for quarter 1 to 3, then press the Confirm parameters button, which displays a message with the data that has just been selected. The next step is to select the number of profiles at the value 2 for the 2nd trimester (as in Fig. 4), then you can confirm and repeat the same steps for the 3rd and 4th trimesters.

Once the parameters have been set and verified, the Remake profiles button will be pressed, which will trigger the determination of the consumer profiles by calling some clustering algorithms.

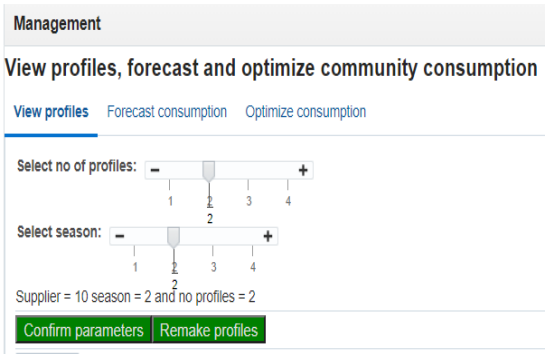

Fig. 4. Selecting the clustering parameters

The result of the analysis will be displayed in tabular form on the same page, specifying for each of the identified profiles the following details: Profile ID, description, type of consumer, quarter (season), off-peak consumption, peak consumption (peak), average hourly consumption and vendor ID. By selecting one of the profiles, details about the consumers associated with that profile will be displayed in a table to the right of the first, as in Figure 5.

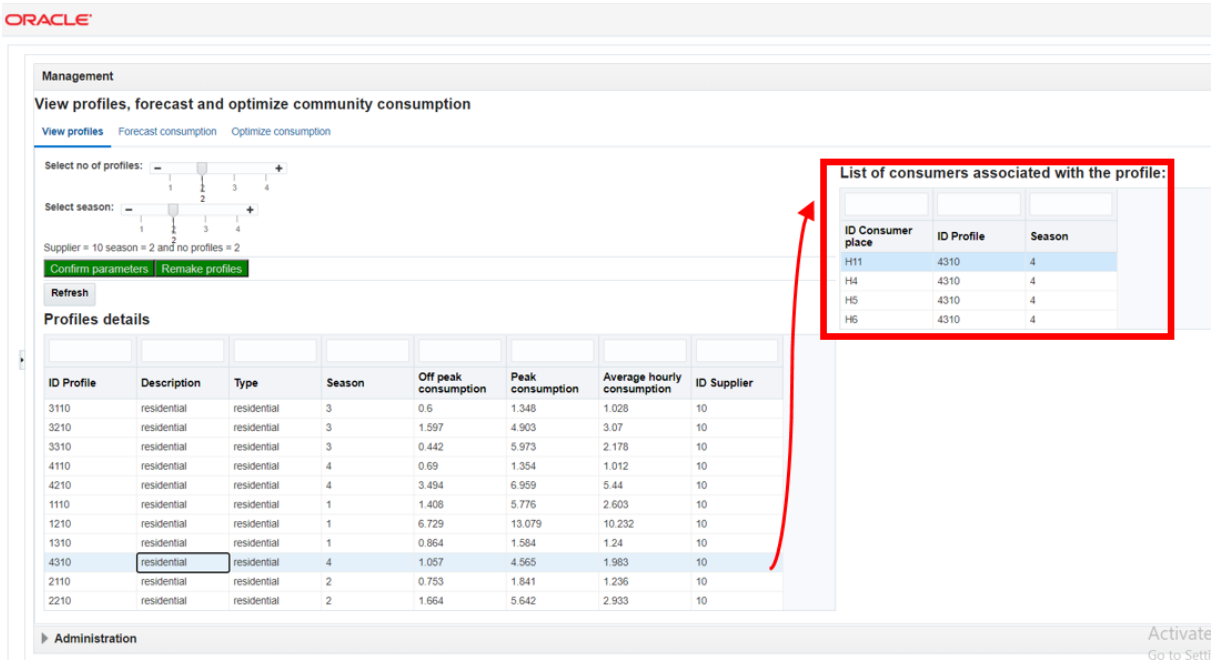

Fig. 5. The resulting profiles and a list of consumers associated with each profile

4.2. Consumption forecast

The electricity forecast is influenced by the weather conditions, the time interval, the season, the type of day (working / weekend), but also by the consumption profile. The electricity consumption is estimated daily for the next 24-hour period for each previously determined consumption profile. To do this, select the day and month for which you want to make the consumption prediction, select the profile and then run the prediction model. Hourly

estimates can be viewed and analyzed by the supplier in tabular and graphical form. The supplier may decide to resume the prediction process for the other consumption profiles. The power consumption prediction model is implemented in Python and can be called within the prototype in the form of a web API [8]. For example, in Fig. 6 the profile with ID = 1112 was chosen and the supplier with ID = 12 was selected on 10/01/2019, then the data were confirmed and the prediction algorithm was run. The results obtained are displayed in tabular and graphic format (Fig. 6).

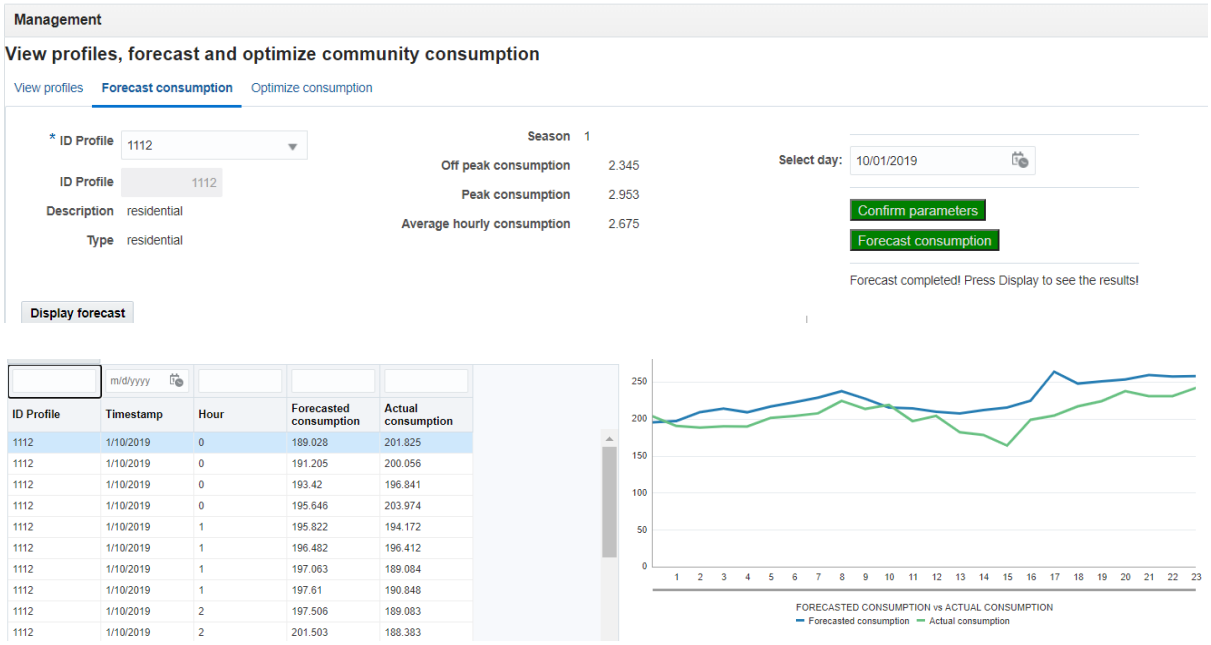

Fig. 6. Results of the forecast algorithm presented in parallel with Actual consumption

4.3. Consumption optimization

In order to optimize the electricity consumption at the supplier level for the next day (day-ahead optimization), four algorithms were implemented, in Matlab and in Python respectively, which use different methods and approaches aiming at flattening the consumption curve at the aggregate level [9].

Each consumer submits for the next day an initial planning of the consumption of programmable devices. Based on the characteristics of the devices (type, maximum consumption, operating steps), electricity consumption estimation, programmable device planning and tariff plans applied to each place of consumption, the algorithms will determine an optimal next day consumption plan for each consumer. so that at the aggregate level the consumption curve is flattened. The supplier analyzes and compares the schedule determined by each algorithm and chooses the optimal plan for the next day.

The Initial schedule is displayed first depending on the type of control, which highlights the initial consumption at each time interval (Fig. 7).

The optimization results are grouped into 3 categories, as seen in Fig. 7: Initial schedule by appliances, Optimal schedule by appliances, Optimal schedule by control type.The Optimal schedule by control type option is the one selected by default, where the control type can take the values:

• NPT - devices whose operation cannot be interrupted and cannot be shifted,

• S - shiftable devices,

• I - devices whose operation can be interrupted and can be shifted,• B - batteries.

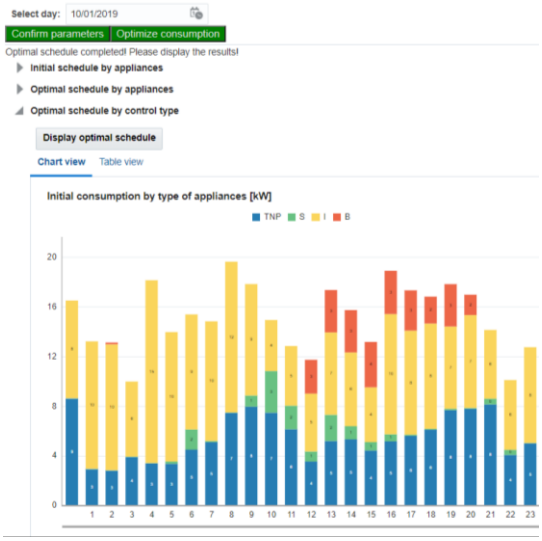

Fig. 7. Initial consumption by appliances type as a graph, and Table view - allows tabular display of data.

Since the optimization was performed by 4 methods, the results of each of them are presented in the form of a graph, as can be seen in Fig. 8.

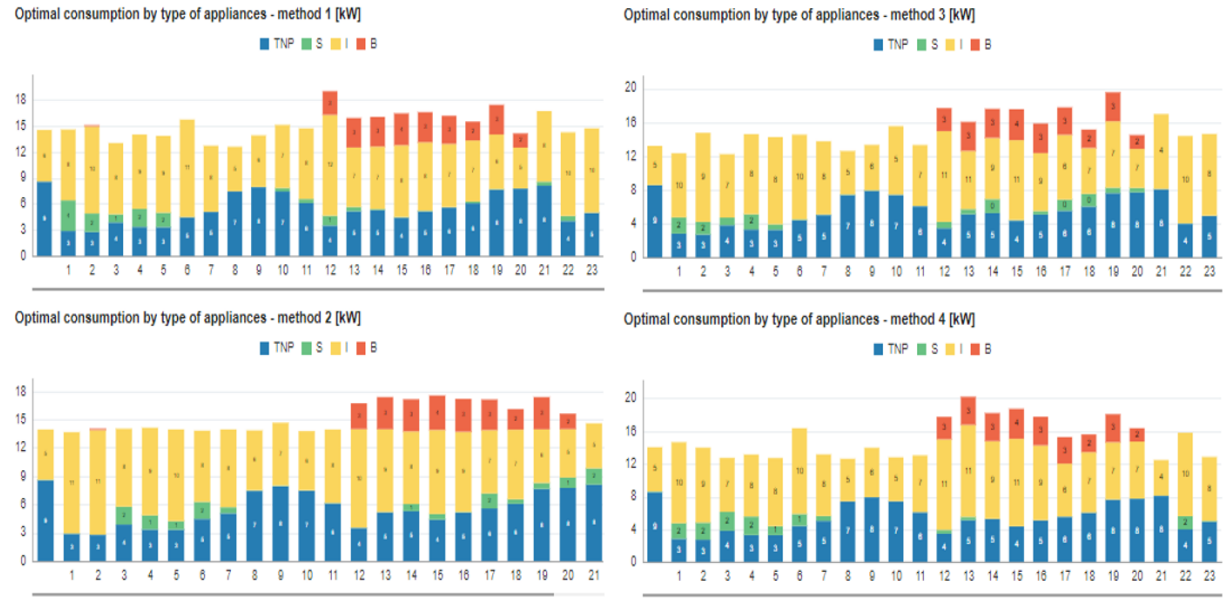

Fig. 8. Optimal consumption by type of appliances by four methods

The Initial schedule by appliances option displays in tabular form the initial device scheduling data for the selected date, displaying for each device the control type, ID, estimated consumption, flexibility, start time, and end time of consumption.

The Optimal schedule by appliances option displays in tabular form for each device the time at which the consumption will take place, the initial consumption and the optimal consumption determined, also based on four optimization algorithms. Such an example is illustrated in Fig. 9.

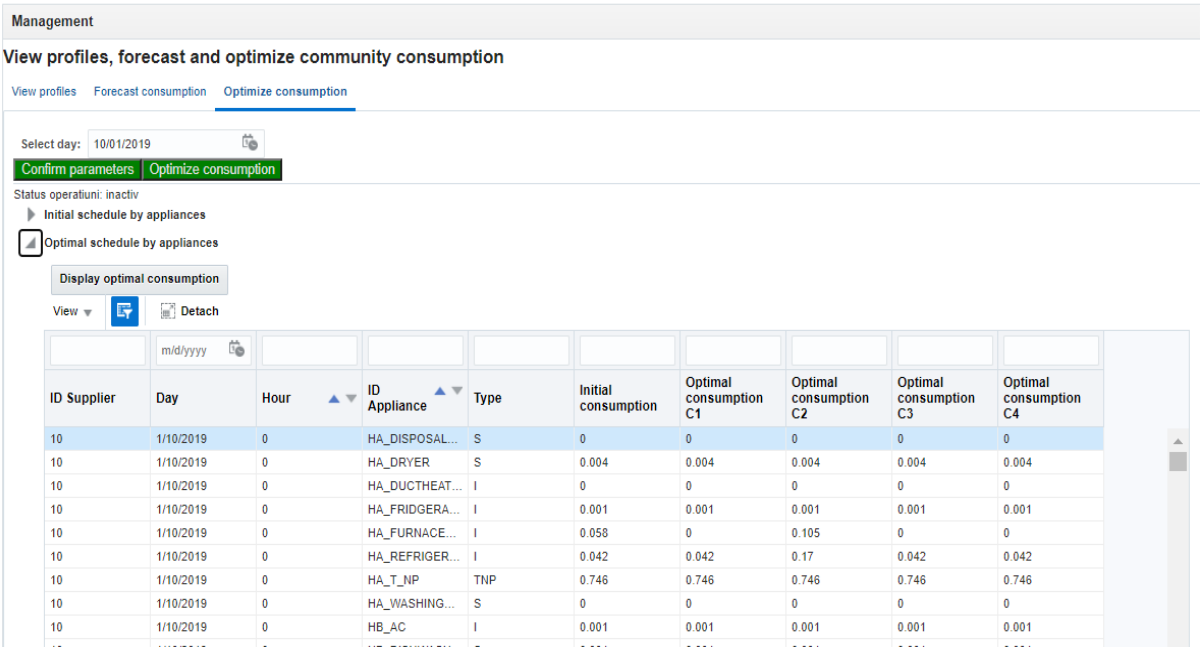

Fig. 9. Display optimal schedule by appliances

5 Conclusions

In order to meet the needs of power suppliers, the authors of this paper have developed a specialized software platform. The software product is designed to perform analysis of historical values, and to elaborate consumers' profile clustering, consumption forecasts and optimization, all for supporting the power suppliers in identifying the necessary information and take the right decisions.

The presented software solution contains the components necessary for the management of electricity consumption, the supplier performing the following activities:

• Manages consumer data based on supply contracts for each place of consumption and type of consumer;
• Carries out consumption profiles based on the clustering model;
• Establishes the tariff plans allocated for each place of consumption;
• Configures smart meters to measure electricity consumption;
• Monitors in real time and for different periods of time the readings recorded by smart meters;
• Monitors in real time and for different periods of time the readings recorded by electrical devices depending on the access granted by consumers;
• Access the prediction model to estimate electricity consumption over different time periods.
• Access power consumption optimization models for optimal planning for the next 24 hours (day-ahead optimization);
• Accesses the electricity consumption optimization model for real-time flattening of peak consumption (dynamic and real-time optimization).

In addition to these elements, integration with an advanced analysis module was achieved.

The dashboards developed based on the data from the EL-Supplier module allow the visualization of the consumption history and the deviations between the forecasted values and the real consumption according to different criteria, and substantiate the strategies for applying the tariff plans according to the consumption profiles.

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